# 29 Implementation of artificial intelligence into risk management decision-making processes in construction projects

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## Abstract

Risk management is nowadays a standard methodology that can be implemented in any construction project; nevertheless, the analysis of risks is in the majority of the cases performed only qualitatively. In addition, formal quantitative methods are needed to provide more certainty for project costs and delays in the delivery process.

Risk management is the application of the risk management process which consists in: Risk identification - Risk analysis - Risk evaluation & response - Risk verification & monitoring - Risk planning & controlling

The state of the art of Risk management in the praxis is described. It is a present challenge implementing the process in construction industry. It is a future challenge to integrate Risk management in every process of a company means "operational", "economical", and "strategical". This Enterprise Risk Management (ERM) will be a need in the future management processes. Key aspects for implementing formally such systems with the private firms or with government agencies are discussed.

Successful Risk management needs effective tools. From the sub processes of Risk management, Risk analysis is the most important for performing an effective quantitative assessment. This paper presents a methodology of how to perform a quantitative risk analysis in order to develop a formal risk management, while joining Artificial Neuronal Networks with the execution of Monte Carlo Simulation.

Artificial Neuronal Networks (ANNs) is one of the new methods from the artificial intelligence field that have emerged and found its applicability in risk analysis. They allow predicting values from de-fined data banks. Monte Carlo is applicable simulating risks, and the initial values are defined by ANNs. Consequently the combination of both methods is a strong engineering tool for the Risk analysis process. The paper demonstrates its applicability in construction projects together with the use data from the praxis.

## Introduction

Risk management is a formal process for assessing and evaluating incertitude that has been formalized in the academic field and with some government agencies around the world. Nowadays risk management is a standard methodology in many different fields of the scientific research. It has been implemented in the industry with several types of projects but its application has been limited to rather small projects and usually just applying a qualitative risk analysis; nevertheless, more work has to be done for standardizing its applicability. Typically, the analysis of risks in the professional arena especially in the construction industry, is performed in the majority of cases qualitatively only. Contractors usually use only checklists in order to identify and categorize risks. The recent global crisis has demonstrated that the utilization of qualitative risk analysis is not enough for assessing properly risks. Quantitative methods are needed to provide more certainty for delivery projects and to reduce cost overruns and delays in the delivery process. In addition, a formal quantitative risk analysis is needed for determining properly the contingency amount in terms of cost and time at the planning phase of the projects, it is recommended to create a risk register for supporting the contingency analysis.

This paper presents a risk management model of how to perform a quantitative risk analysis in order to develop a formal risk management system while integrating artificial intelligence and probabilistic methodologies. Additionally, it discusses key aspects for implementing formally such system with the private firms or with government agencies.

## 29.1 Concepts

### 29.1.1 Risk and uncertainty

Risk management has become an essential procedure in the development of any construction project; nevertheless its implementation involves the use of the basic concepts such as "Risk" and "Uncertainty". These concepts are often confused and utilized like synonymous, even when they are completely different (see Figure 1). Knight [249] in 1921 differentiated them based on their quantifiability.

- ***Risks:*** are identifiable and quantifiable possible events or factors; from which, negative (hazards) or positive (chances) consequences may occur [250].
- ***Uncertainty:*** refers to unknown and unforeseeable events or factors; which no quantification or almost no identification is possible [251].

Therefore it's important to differentiate between these two concepts; most of the risks are possible to identify and control, they can be sorted in Hazards and Chances, while uncertainties are always unexpected and/or not quantifiable.

[249] (Knight, 1921)
[250] (Sandoval-Wong, et al., 2009)
[251] (Sandoval-Wong, et al., 2009)

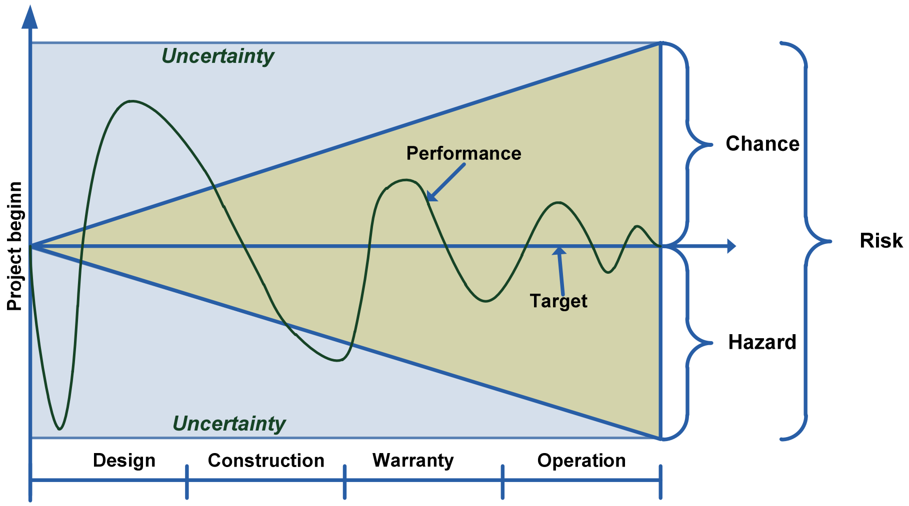


Figure 1: Risk and Uncertainty (Sandoval-Wong, et al., 2009)

The Figure 1 presents the behavior of the uncertainty and risk through the different project phases. At the early phases the uncertainty has a major influence into the project environment than risks; consequently, as the project progress along the development phases the presence of risks become higher than the uncertainty, mainly because uncertainties are identified and quantified as specific project risks. Afterwards they are managed in order to achieve the project chances and to avoid its hazards.

Risks can be also understood as deviations from a desired target; Daniel Bernoulli in 1738 defined Risk as simple as a possibility multiplied by its impact [252]. It is this reason that by the application of risk management, dualism of "Chances" and "Hazards" must be taken into account.

## 29.1.2 Risk management

The controlling and handling of risks is known as "Risk Management" (RM); it can be defined as "*a structured approach to administrate (analyze, evaluate and control) risks*" [253]. Risk management involves the application of the "Risk Management Process" (RMP), which is a logical sequence of steps in order to analyze and manage risks and through them, to lead them to the main endeavor's goals (see Figure 2).

Risk management is the application of the risk management process which consists of:

- ***Risk identification***
  In this sub process the main task is to discover all the possible risks that might have an impact on the project´s objectives. After the identification, the corresponding

[252] (Bernoulli, Daniel, 1954)
[253] (Maria-Sanchez, 2005)

probabilities and impacts must be quantified. For this sub process, methods as “Check lists”, “Brainstorming” or “Pondering” provide an important aid.

- ***Risk Analysis***
  The second sub process assists in the quantification of the probabilities and impact of each factor (risks); for this several methods like Var at Risk, Delphi, Monte Carlo Simulation, etc. can be used. Risk analysis can be qualitative only, but it should be quantitative. For example, with the assistance of stochastic models a quantitative risk analysis can be performed.
- ***Risk evaluation & response***
  After the quantification and determination of the probabilities and impacts, the management of the possible results takes place. Typically the response strategies are avoidance, transfer, mitigate, etc. As well, risk owners are assigned to each risk to help to implement the strategies and also to assist the project manager in providing the status of the risk.
- ***Risk verification & monitoring***
  Subsequently to the definition of the needed actions to handle the risks, a supervision and control system has to be developed aimed to identify deviations of the defined goals (settled in the previous process).
- ***Risk planning***
  Risk planning is about defining and designing the strategy for implementing the whole life cycle of risk management for one project as a pilot program, for many projects or for implementing a formal process with the organization. Risk planning quantifies the resources needed, defines the roles and responsibilities of each member of the risk team, designs the risk team and establishes the formality of risk management with a company directive or memorandum. Risk planning is the critical path of the risk management system because it outlines those tasks and processes that are crucial to be deployed in order to be successful.
- ***Risk controlling***
  Risk controlling involves all the risk metrics necessary to track any change in the risk behavior towards the project objective. The change in the risk can be attributed to an impact into the cost, time, quality or scope of the project. Risk controlling is an opportunity to evaluate the effectiveness of the risk strategies and also provides a basis for the decision-making in order to control the overall target of the project. It is also an important tool for the further development of the Risk Management Process, for its communication procedures and the Risk planning.


Figure 2: Risk Management Process (RMP)

### 29.1.3 Risk analysis methods

Risk analysis methods deal with the evaluation of risks; risks quantification means that probabilities can be associated to expected values or results; however its effectiveness depends on the previous steps in the RMP because those steps are the foundation of the whole process. The planning process for implementing risk management is a crucial phase, it provides the opportunity to the project and risk managers to explain and describe in details what risk management is about, why it is important to have a risk team, what is expected from them and what are the deliverables. Consequently risk reporting and communication play a critical role under the risk analysis process; it is also a great opportunity to explore with the team any doubts or questions about the risk management process and also a chance for convincing the project stakeholders, the executives and the rest of the team about the benefits of implementing a serious quantitative risk analysis.

Risk analysis is the most important milestone for performing an effective quantitative assessment. All these processes define the requirements to be attended on the search of inputs and the definition of stochastic models and their functions; consequently the utilization of quantitative methods like Monte Carlo Simulation shall become a requirement for risk analysis. Checklists are mostly used for risk identification; they are necessary and useful for the identification but not sufficient for the analysis.

The following risk analysis methods dispose adequacy and opportunities for quantitative risk analysis:

- Monte Carlo Simulation (MCS)
  (Widely used by Risk analysis practitioners)
- Artificial Neuronal Networks (ANNs)

(Method from the artificial Intelligence field, with high potential in Risk analysis)

- Support Vector Machines (SVM)
  (Recently developed method from the artificial Intelligence field, with high potential in Risk analysis)

#### 29.1.3.1 Monte Carlo Simulation (MCS)

MCS permits to perform simulations from a predefined model and in this way to generate scenarios through a random generator number. The model is based on a deterministic procedure which provides a mathematical process; the outcomes of these calculations are the expected results or values for or from all the criteria (targets or expectations). However it is known that most of the criteria do not have a deterministic behavior, therefore these criteria fluctuates between a determinate range (normally minimal and maximal values, see Figure 3). Under this consideration different criteria (risks) are identified with their corresponding inputs (fluctuations) together with the correlation between the identified risks to each other.

MCS permits to fit the behavior of the several risks into determinate distribution curves (for example Pert, Normal and Triangle distributions), this means that the MCS works with the inclusion of assumptions for every of the identified risks and associates their behavior to the distribution curves and the maximal, minimal and expected value. In some cases, only maximal and minimal input values are used, mostly because in some cases it is not that easy to obtain the expected value (most likely) from the experts or the risk team.

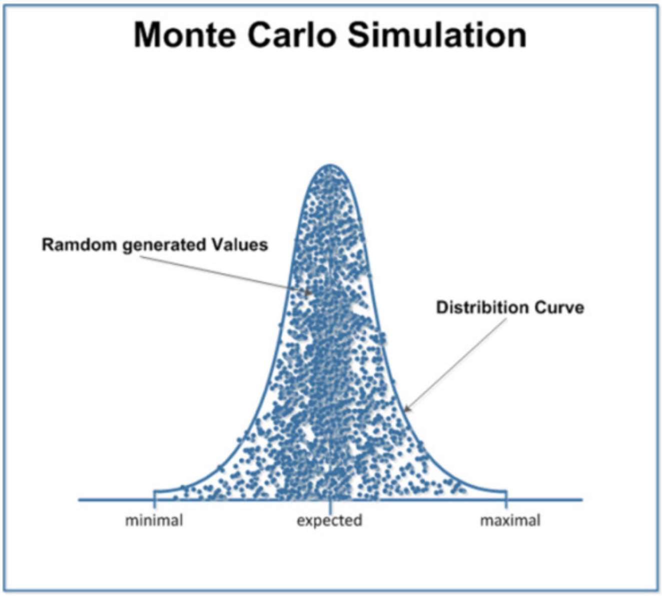


Figure 3: Monte Carlo Principle (Pert Distribution)

Figure 4 presents how to perform a risk analysis with MCS. The risks are identified and evaluated, from this first evaluation the corresponding distributions and correlations are linked to the whole data in the mathematical model. Through the random generator number, simulations are performed and as result probability density and cumulative graphs are obtained (often included is a sensitivity analysis tool), through their analysis the probabilities of desired targets can be estimated. A critical aspect for the modeler is to select the appropriate distribution function according to the data available, the nature of the data or also the behavior of the data in the practice, normally based on an available database.

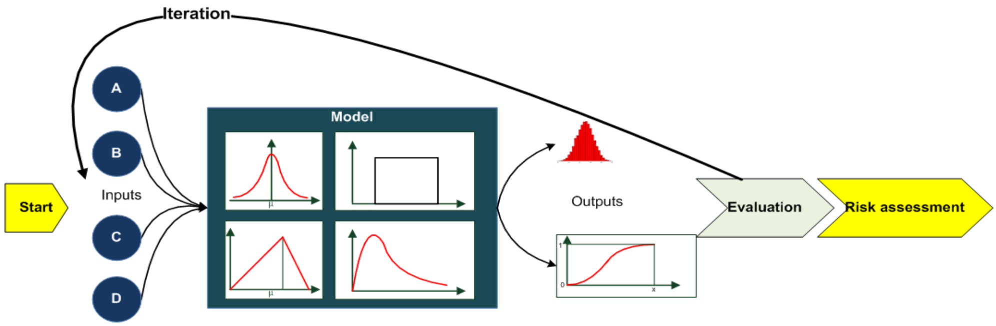


Figure 4: Monte Carlo Simulation Procedure

### 29.1.3.2 Artificial Neuronal Networks (ANNs)

Although this technique is relative new in the commercial world, the original theory was developed in the 60´s together with the algorithms and some theoretical approaches. Nevertheless, the lack of capacity with the computers´ processors kept this technique in the shadow for many years. ANNs contain with their structure, different sections of layers, the middle ones usually are called the hidden layers. The conceptual process of ANNs is conformed of an input vector, a transfer function and an output vector (see Figure 5). The transfer function with its limits is very often called a “black box”, this is because at this phase an internal process for adjusting and calculating new weight for the network is performed and this process is not observed by the modeler or the designer.

The main advantage of ANNs is that the whole process (training and testing) mimics the human’s brain reasoning. In other words, it learns by the experience: Once a good database is developed the chances to obtain reliable predictions with ANNs are very feasible.

One example of the practicability of the ANNs is the Neuronal Risk Assessment System (NRAS) developed by Maria-Sanchez. [254] This method shows a very practical manner for implementing ANNs for assessing the risks in infrastructures projects. The main goal of the system is to determine the contingency amount based on specific project risks. The results show the capabilities of ANNs to mimic the data, offering a great new approach for

[254] (Maria-Sanchez, 2005)

performing risk analysis. In addition, nowadays it is possible to find commercial available ANN tools [255].

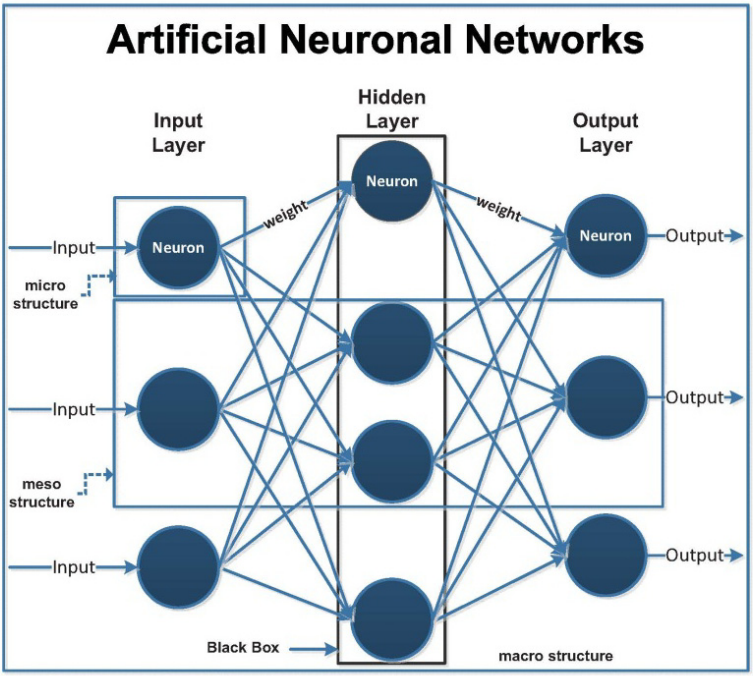


Figure 5: Artificial neuronal Networks Functionality [256]

### 29.1.3.3 Support Vector Machines (SVM)

The SVM is a method from the artificial intelligence that has shown high potential for its applicability in the risk analysis. [257] Vapnik defines this method as a statistical learning theory; [258] it works under the identification, screening and separation of the data in hyper planes based in a support vector. In this form the data are classified in several dimensions (hyper planes); as a second step simulations are executed by creating data inside of the several hyper planes. The SVM permits to learn from a defined database and from this learning process to forecast possible results, in this form it is possible to perform simulations with a higher liability derivate from the learning process.

From these three methods SVM represents a very promising method because it permits to learn from the data and simulating without assumptions (like MCS); the simulation is

[255] For this example Neural Tools by Palisade
[256] (Maria-Sanchez, 2005)
[257] (Sandoval-Wong, et al., 2009)
[258] (Vapnik, 1995)

based on the identified hyper planes, which increase certainty, however the method is based on the artificial intelligence theory and requires a considered amount of data to perform its learning process.

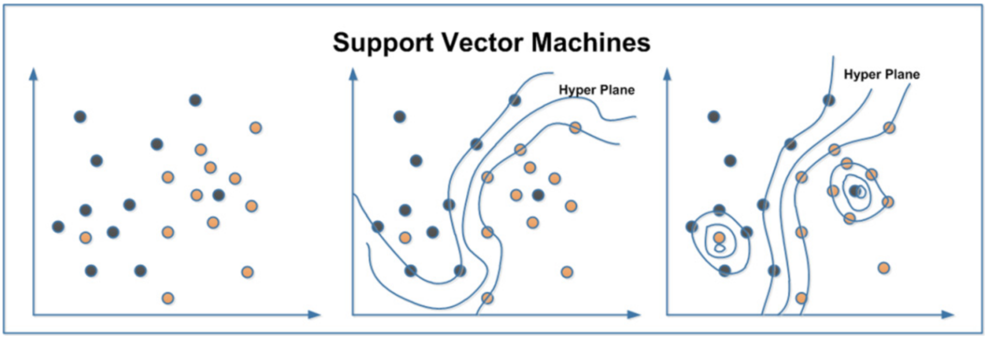


Figure 6: Support Vector Machines Functionality [259]

SVM permits to integrate a learning process with the performing of simulations based in the random generation numbers for a better forecast of risks, nevertheless there is until today no commercial software for its utilization in the praxis. For this reason and for the practical purpose of this work, SVM is only mentioned as a possible future commercial tool but is not included in the model and simulation (see Table 1).

| *Method* | *Required Inputs* | *Learning Process* | *Robustness* | *Appliance-Software* | *Random generated Number* |
|---|---|---|---|---|---|
| ***Monte Carlo Simulation*** | Just three or two Values needed (minimal, expected and Maximal) | not possible | In directly relationship of the mathematical Model and the Inputs | Many commercial Software in the market | *Simulations* based on it |
| ***Artificial Neuronal Networks*** | Data Banks indispensable | Based in Learning from Data | High because of its learning Process | Some commercial Software in the market | Not Possible |
| ***Support Vector Machines*** | Data Banks indispensable | Based in Learning from Data | High because of its learning Process | No commercial Software in the market | Possible to - based on it |

Table 1: Comparison between MCS, ANNs and SVM

## 29.2 Risk Management in the Praxis

The current practice towards risk management in construction projects have shown, that there is a high need for understanding which benefits provides a formal risk management implementation and consequently to know which procedures should be included into the risk management system itself. It is important to remark that Monte Carlo Simulation begins to become a wide accepted risk analysis method in many different fields including the construction industry; this technique has been proved to be a reliable risk analysis tool for evaluation almost all sorts of infrastructure projects through the different phases.

[259] (Sandoval-Wong, et al., 2009)

It is true that usually risk management is implemented only partially in the construction industry, in other words, usually a risk register and a qualitative analysis are done without developing stochastic models. The level of risk management depends on many factors; for fairly straightforward projects perhaps are acceptable, however, for capital projects, a quantitative analysis is a must.

The future of risk management in the construction industry has many challenges, especially because any extra effort for assessing the projects needs to have a proven track record of success and requests benefits that otherwise, the practitioners will not be interested to use.

### 29.2.1 Risk Management Problematic in the Praxis

Even when risk management is a recognized and essential procedure within any construction project, its application is until today very limited. Self the understanding of the concept is very often vague and it is completely different understood between partners and branches, therefore it becomes also important to unify or even to try to regulate the terms.

A survey demonstrated that risk is understood in different forms by German Banks, Insurance firms, Funds and Industry, [260] hence there is the need to speak the same risk-language at least between partners; nonetheless the problem goes even further, according to a recent study of Bauhaus University of Weimar. [261] Most of the constructors in Germany don't utilize risk analysis methods that permit to realize simulations or to elaborate risk analysis from a quantitative basis (quantitive stochastic models). Most of the constructors perform just cost benefit analysis, sensitivity analysis [262] and scenario analysis, which permits to perform qualitative to quantitative analysis but not the desired quantitative risk analysis; the reason is that these methods permit to valuate criteria and their interactions to each other, but not to vary the criteria values and trough it, to estimate probabilities.

Even when Monte Carlo Simulation is one of the most accepted risk analysis methods for Risk analysis practitioners around the world, the study of the University of Weimar permits to appreciate that in the German construction industry, it's still not wide utilized as expected, just less than 10 % of the contractors mentioned to know the method. One of the central reasons of the utilization of only qualitative risk analysis methods is the lack of knowledge about the benefits and chances provided by quantitative risk analysis and as consequence, from the risk management process (see Figure 2). In addition, many practitioners are anxious of using simulation for many reasons, mainly by the lack of knowledge about the technique´s benefits, causing this a misunderstanding of how use the tool properly.

At the end, some professionals believe that this methodology can add confusion to the project development. The challenge for those people supporting the enhancement of risk management is to convince by real examples, benefits and to deliver comprehensible risk reports for all sorts of management levels.

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[260] (Managers, 2010)
[261] (Alfen, et al., 2010)
[262] Sensitivity analysis shall never be considered as a risk analysis method. (Smith, et al., 2006)

### 29.2.2 Enterprise Risk Management (ERM)

Risk management has to be implemented for projects or within projects, but this is only the first step. Risk management means a change of doing business. For that reason, the culture of implementing Risk management should be brought by the executives and the company´s policies. Risk management has evolved into the "Enterprise Risk Management" (see Figure 7).

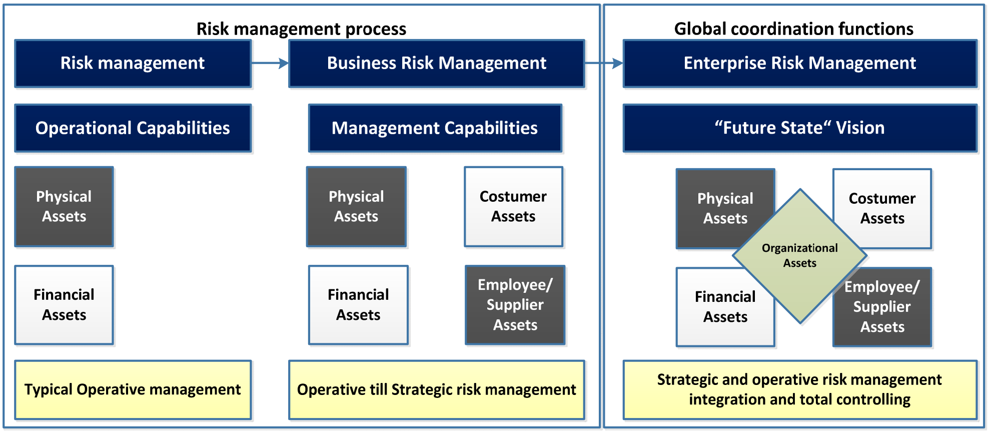



Figure 7: Risk Management Evolution based on (Protiviti, 2006)

This new methodology explains that there are different philosophies about risk management with their own methods and focus; these are normally classified in four different types. [263]

- the Risk Silo Management (Operational Risks),
- the Integrated Risk Management (Economic and Capital Risks),
- the Risk and Value Management (Management and Performance) and
- the Strategic Risk Management (Senior Management and Strategical Risks).

ERM is in charge to unify all this philosophies and confer the determination of one whole risk in a corporation. One of the most important topics handled by the ERM is the determination of the Risk Appetite. The Risk Appetite is: "*the quantum of risk that the firm is willing to accept within its overall capacity*". [264]

In order to propitiate the ERM in every company, the standard "ISO 31000:2009 Risk management - Principles and guidelines" is a comprehensive guide of how companies should implement a formal risk management process. It sets out principles, a framework and a process for the management of risks that are applicable to any type of organization in public or private sector. It does not mandate a "one size fits all" approach, but rather em-

[263] (Mikes, 2005)
[264] (Barfield, 2008)

phasizes the fact that the management of risk must be tailored to the specific needs and structure of the particular organization. It depends at the end of the company´s desire to be competitive and willing to manage proactively risks and opportunities.

The Figure 8 describes the overall implementation status of risk management in the construction industry. A reality of risk management with construction companies is that in the industrialized world, these companies have a better understanding of the necessity for analyzing and managing risks. Nevertheless, construction companies from non-industrial countries are usually not aware about the existence of risk management since their basic necessities for surviving as an enterprise are different than the environment that a company from a developed countries commonly faces and in addition; the construction industry in third world countries is more traditional with less technology involvement.

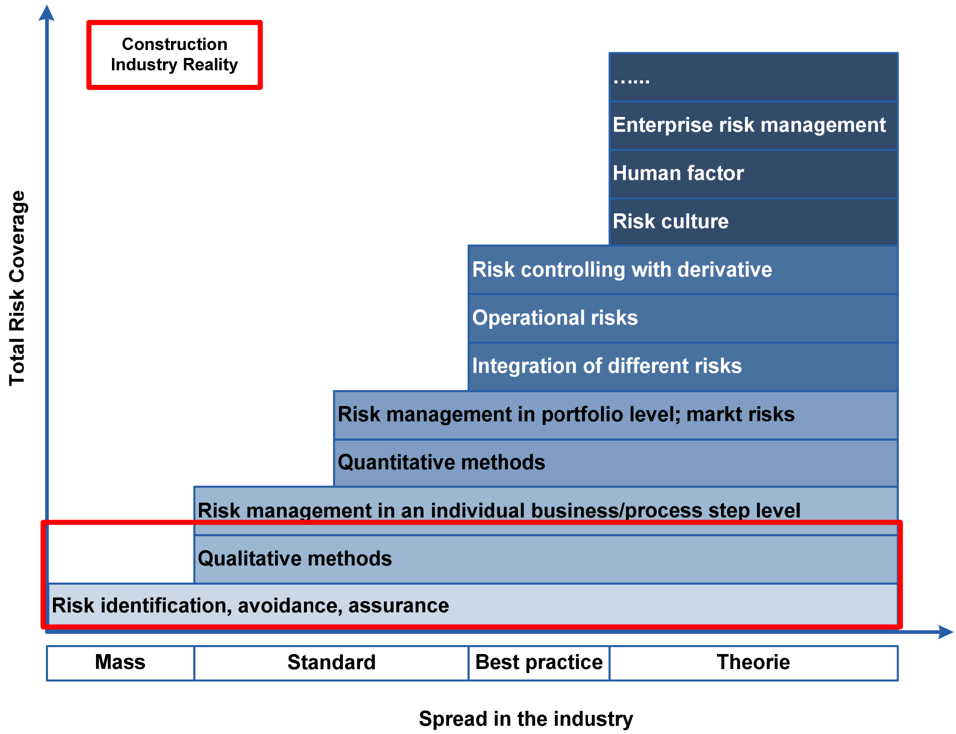



Figure 8: Risk management spread in the industry, based on (Lausberg, 2008)

## 29.3 Proposed Methodology

The Support Vector Machine could emerge as a methodology of the artificial intelligence that will be used in risk analysis; it allows in a first step to perform a learning process to screen and separate the previously collected information in hyper planes. As second step, it implements a simulation process in order to convey probabilities to the predicted risk or value. But the utilization of risk analysis in the praxis depends of the availability of the required tools to perform this type of analysis for the risk analysis practitioners. Until today there is no commercial application of the SVM, (see 1.3.3) therefore for its employment is necessary to create computer programs.

Thus the combination of ANNs and MCS shall emulate its functionality, from existing commercial programs. The disadvantage of MCS is the use of assumptions in its procedure. This can lead to dispersion increases with the inputs and in the corresponding delivered results, or in in the worst case, into errors and misconceptions; for example when the risk analyst does not have enough experience, can create an ambiguous environment to the whole process and this can affect the quality and results of the entire implementation.

MCS allows simulating risks but the inputs still need to be defined as part of the qualitative analysis. Better inputs can be found by ANNs: They allow predicting values from defined data banks; accordingly it represents an important aid for the definition of inputs for the MCS. Consequently the combination of both methods shall reduce the possibility of mistakes, by defining the initial values with the ANNs and using MCS for the simulation process.

ANNs is one of the new methods from the artificial intelligence field that have emerged and found its applicability in risk analysis. It has two key steps for implementing in risk management, however a considerable database is needed in order to train and test the network. Different network designs can be achieved and for some algorithms, the training and testing process can be more easily achieved if the design is efficient and practical.

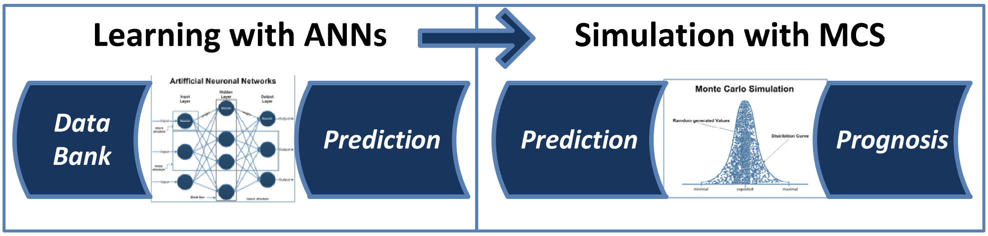



Figure 9: Proposed Methodology ANNs + MCS

The proposed methodology mimics the functionality of SVM and of the human brain. When a new estimation is required, the estimator normally evaluates the undertaking making a review of the available information; the estimator carries out the evaluation based on his own data and delivers a bordered estimation. By the SVM, this task is performed in the learning process, specifically by the definition of hyper planes (support vectors); hereto the ANNs emulate this process and deliver a prognosis for its further evaluation.

As a second step the information gained is handled in MCS that permits to perform simulations under the assumption of behavior curves, the reliability of the results in MCS is increased by the learning process of the ANNs. The simulations process is also developed by the SVM utilizing the hyper planes defined in the learning process; nevertheless, it is important to mention that building and designing the database is crucial for setting up the basis of the system. The whole system will rely on this database, and the risk managers should perform quality assurance frequently to the data.

Another relevant issue of this new methodology is the interface while transporting the ANNs results into inputs for the MCS simulation. Nowadays, it is possible to use both, ANNs and MCS with user friendly software. This fact is a plus for any risk manager because it provides confidence while basing the analysis in a very well-known system.

## 29.4 Example

In order to clarify the proposed methodology the following example was prepared: For an excavation activity, a wheel loader and trucks will be utilized. Therefore, first the wheel loader´s production shall be determined and with this data, the number of the required trucks will be calculated.

### 29.4.1 ANNs Prediction

The application of the ANNs needs a data bank of the effective capacity depending on the relevant criteria. For lack of measured site data it was created based on the formula and values by means of the addition method in construction machines. The data bank includes a number of 12 criteria; through the formula we can determine the "exact" result (important for the test of the ANNs) of the effective capacity. For each of the 12 criteria a range was determinate and through the utilization of a random generator number 1000 different result combinations were created, having the result and criteria a direct relation.

Table 2 presents part of the Wheel Loader Data Bank; the last right column presents the machine's effective capacity in m³/h and is the dependable variable. The 12 criteria are a mix of text and numbers.

**Loading with Wheel loader (Addition's methode)**

| Wheel Loder Type in [min] | Soil Class in [min] | Excavation height in [min] | Subsoil in [min] | load conditions in [min] | Driver performance | Cycle in [min] | Efficiency [---] | Cycle per Hour [At/h] | Shovel volumen in [m³] | level of filling [---] | Effective Shovel capacity in [m³] | Effective capacity in [m³/h] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,40 | 0,00 | 0,00 | 0,05 | 0,05 | middle | 0,50 | high | 96 | 1 | clay,sandy,wet | 0,9 | |
| 0,28 | 0,09 | 0,44 | 0,10 | 0,00 | bad | 1,01 | bad | 36 | 3 | Sand,gravel,wet | 3 | |
| 0,47 | 0,03 | 0,11 | 0,03 | 0,00 | bad | 0,70 | bad | 51 | 2 | rocks, well closed | 2,2 | 112,9 |
| 0,24 | 0,07 | 0,13 | 0,07 | 0,00 | good | 0,46 | very high | 119 | 1 | clay,sandy,wet | 0,8 | 94,9 |
| 0,04 | 0,08 | 0,00 | 0,02 | 0,02 | middle | 0,16 | very high | 343 | 1 | clay,sandy,wet | 0,8 | 274,3 |
| 0,37 | 0,07 | 0,31 | 0,01 | 0,08 | good | 0,76 | very high | 71 | 2 | Sand,gravel,wet | 2 | 142,9 |
| 0,04 | 0,00 | 0,21 | 0,07 | 0,06 | good | 0,35 | very high | 154 | 3 | Mixed soil, wet | 3,6 | 553,3 |
| 0,52 | 0,03 | 0,26 | 0,15 | 0,00 | good | 0,87 | bad | 41 | 1 | Mixed soil, wet | 1,2 | 49,7 |

Table 2: Wheel Loader Data Bank [265]

The text criteria were created with the utilization of numerical data and they were replaced with text for its testing in ANNs. At the end every formula was deleted, remaining just the numbers and text without any relation rule, for the evaluation of the ANNs.

ANNs provides the estimation of the production based in the Data Bank [266], the normal procedure by ANNs is as follows (see Figure 10): The Data Bank must be elaborated and loaded into the ANN program, the independent and dependent criteria must be specified. As a second step, the learning process (training) for the ANNs has to be defined as well

[265] The information utilized in this table, are Data earned by a previous research (Jockusch, 2010).

[266] for this task the software "Neuronal Tools" of Palisade was employed

with the error tolerance. Afterwards when the learning process is concluded, the trained ANN must be tested for its liability. When the testing process is successfully achieved, the prediction takes place.

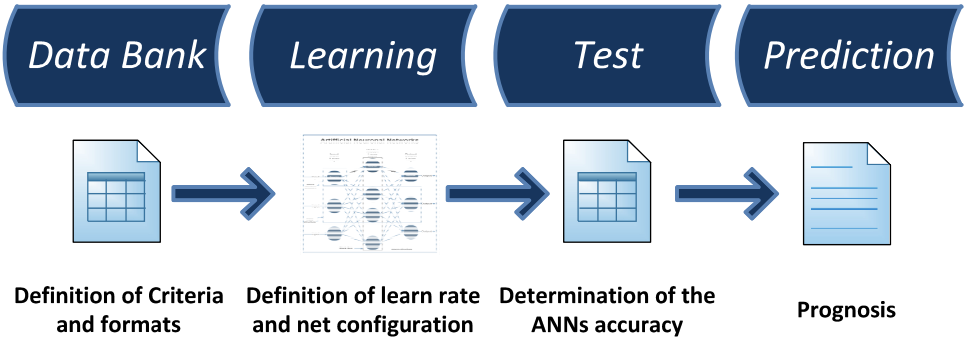



Figure 10: ANNs functionality

For the present example two results/outputs were searched. It is important to remark that these two results were known by the formula, thus it was significant to verify how reliable were the results produced by the ANNs.

The results determined by the formula (known Data) were: 86.4 and 107.2 m³/h (first two lines of the Table 2). For the test, five different ANNs configurations were developed and the network with the most accurate results was chosen for the final prediction. The predictions delivered by the selected ANNs were 83.3 and 107.2 m³/h. This represents a variation of 1.199 % and 0.0932 % respectively (see Table 3). Under this scenario, the learning process delivered dependable predictions for the selected example.

| | | | Prediction Report: "Ne | | | |
|---|---|---|---|---|---|---|
| **Effective Shovel capacity in [m³]** | **Effective capacity in [m³/h]** | | Tag Used | Prediction | | ***Target*** |
| 0,9 | | | predict | 83,3 | | **86,4** |
| 3 | | | predict | 107,1 | | **107,2** |
| 2,2 | 112,9 | | | | | |
| 0,8 | 94,9 | | | | | |

Table 3: ANNs Prediction (Neuronal Tools)

## 29.4.2 Simulation with MCS

The prediction process of the ANNs permits to delimit the expected value to a small range for its further utilization in the MCS. This last method permits to simulate different scenarios, from previously collected factors or criteria and in this from to assess the probabilities of reaching the expected value. Thus the ANNs learning process support the provision of better and more accurate inputs pro it’s processing.

As a second step the number of trucks required for the Wheel Loader was determined, for this task another formula was utilized as base for the MCS – Model. For its comparison two valuations were made, the first one with the use of the results provided by the ANNs (in this case 107.1 m³/h) and the second by Pondering of the Wheel Loader production. For procurement of the Pondering Inputs the qualitative appraisals from an estimator were considered. The Table 4 presents the MCS – Model with the corresponding results. [267]

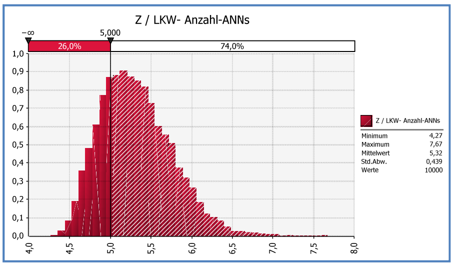
| Required Trucks - Wheel Loader - ANNs | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Criteria** | **ANNs** | $V_R$ [m³] | $f_L$ | $t_B$ | $V_V$ | $t_V$ | $t_K$ | $t_W$ | $V_L$ | $t_L$ | $t$ | $n$ | $Q_0$ | $F_E$ | $Q_N$ | $Z$ | $Z$ |
| **Value** | 107,1 | 17,00 | 0,81 | 7,71 | 30 | 12,00 | 0,70 | 0,50 | 45,00 | 8,00 | 28,91 | 2,08 | **28,57** | 0,75 | **21,43** | 5,00 | **5** |
| **min** | 105,0 | - | 0,75 | - | 15,00 | - | 0,50 | 0,30 | 35,00 | - | - | - | - | 0,60 | Probability | | 26,0% |
| **erwart** | 107,1 | - | 0,81 | - | 30,00 | - | 0,70 | 0,50 | 45,00 | - | - | - | - | 0,75 | - | - | - |
| **max** | 109,0 | - | 0,85 | - | 32,00 | - | 0,75 | 0,55 | 47,00 | - | - | - | - | 0,85 | - | - | - |

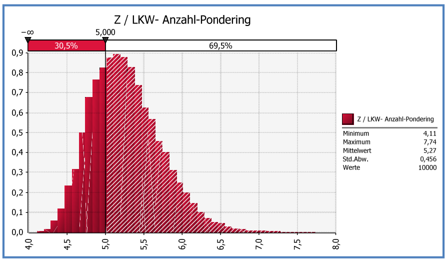
| Required Trucks - Wheel Loader - Pondering | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Criteria** | **Pondering** | $V_R$ [m³] | $f_L$ | $t_B$ | $V_V$ | $t_V$ | $t_K$ | $t_W$ | $V_L$ | $t_L$ | $t$ | $n$ | $Q_0$ | $F_E$ | $Q_N$ | $Z$ | $Z$ |
| **Value** | 105 | 17,00 | 0,81 | 7,87 | 30 | 12,00 | 0,70 | 0,50 | 45,00 | 8,00 | 29,07 | 2,06 | **28,42** | 0,75 | **21,32** | 4,93 | **5** |
| **min** | 98,0 | - | 0,75 | - | 15,00 | - | 0,50 | 0,30 | 35,00 | - | - | - | - | 0,60 | Probability | | 30,5% |
| **erwart** | 105,0 | - | 0,81 | - | 30,00 | - | 0,70 | 0,50 | 45,00 | - | - | - | - | 0,75 | - | - | - |
| **max** | 116,0 | - | 0,85 | - | 32,00 | - | 0,75 | 0,55 | 47,00 | - | - | - | - | 0,85 | - | - | - |

Table 4: MCS Model required Trucks

From the MCS we can conclude that five trucks are required for the Wheel Loader, this with a probability of 26.0 % for the results given by the ANNs and 30.5 % by Pondering. This result could seem like with the utilization of pondering the probabilities are increased, but we can assure that it only means that the dispersion of the criteria is bigger and as result the dispersion of the prognosis is also bigger, thus the cumulative sum of the probabilities is bigger than by pondering.

This can be better understood when we consider the range comprised by the estimations, the utilization of ANNs permits to reduce the range's broadness. The range between minimal and maximal value is about 3.7 % on the ANNs while by the pondering is 17.14 % of the expected value. This affects directly the results delivered in every MCS iteration; finally it increases the range's broadness in the result and the histograms (see **Figure 11** and **Figure 12**).




[267] The simulations were performed with the software "@Risk" of Palisade.

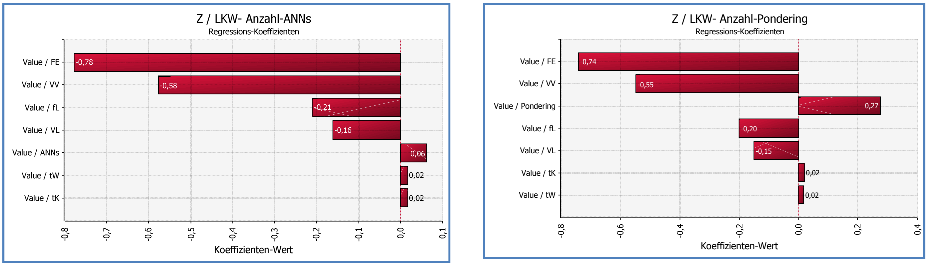



Figure 11: Histograms and Correlation Results of the MCS Models (@Risk)

The histograms (Figure 11) allow to see how the accumulated probabilities are higher by pondering them with the use of ANNs, the broader range of the inputs provided by pondering affects the results of the histograms, therefore the accuracy of the results is reduced and the range's broad of the results is wider. On the other side the prediction made by the ANNs permits to reduce this range and in consequence to reduce the dispersion of the results created by the non-quantitative analysis of pondering. The tornado diagrams support this conclusion; the influence of the criterion production is reduced from 0.27 by pondering to 0.06 by ANNs.

Finally the direct dispersion comparison in Figure 12 presents the generated numbers made by MCS, the red items are the random generated numbers by pondering and the blue ones are the values produced from the ANNs, which confirms the accuracy of the enhancement (dispersion reduction) with the utilization of ANNs for forecasting inputs for MCS.

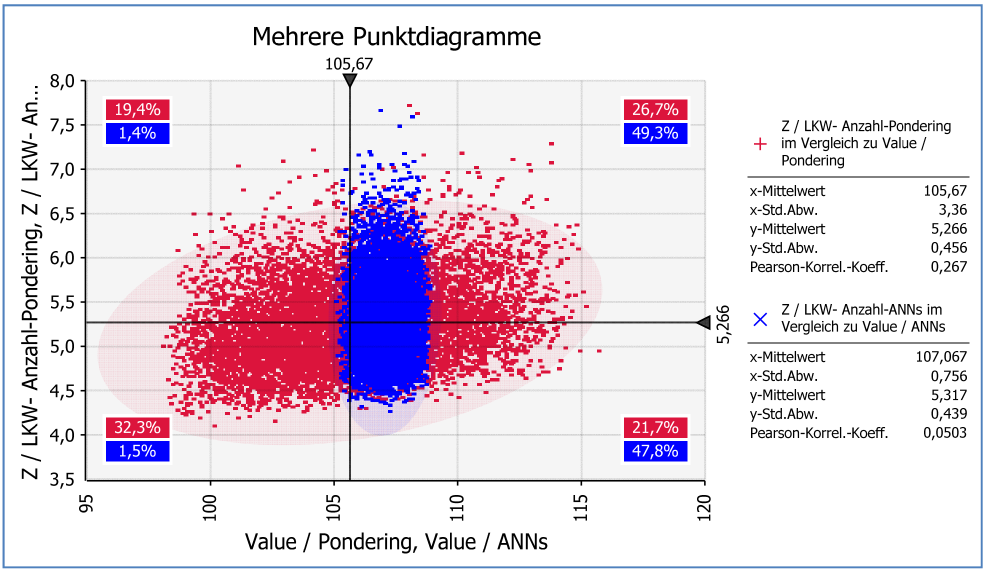



Figure 12: Direct Dispersion comparison ANNs-Pondering (@Risk)

Figure 13 presents the general overview of the proposed RMP methodology in this paper; every step within the process represents an important task with specific assignments. Risk planning has as targets the definition of goals, RM teams, criteria and the selection of Data banks (if available). Within the second step, the risk identification takes place and risks and uncertainties are identified. The use of pondering, checklists and expert interviews are recommended. When a Data bank of the recognized risks is available, it will be provided to the risk analysis for its utilization with ANNs. Risk analysis as third step is in charge of performing a quantitative analysis for the different criteria identified and delivered by the two preliminary processes. Therefore the importance of these processes, the results provided by the analysis will only reflect the quality of the previous processes.

With the proposed methodology, it is possible to analyze the criteria with ANNs while using Data banks and finally feed the MCS-Model with its results. However when there is no database available, pondering, expert interviews, Delphi, etc., can be implemented and the qualitative inputs can be applied also into the MCS-Model, finally the risk analysis report is delivered to the PMs. Input for the databank will be the result of Risk controlling as fifth sub process.

The most important process from the project manager's point of view is the risk evaluation & response. The risk manager has as principal task to deliver a risk analysis report in the way that every project manager can understand in order to facilitate the decision making process, the improvement of the report's format is a central task for this reason and for the communication itself. Thus the PMs outline the actions to for managing the risks; therefore they define new goals and methodologies to monitor and control the risk plan and finally the creation of the controlling teams and communication mechanisms.

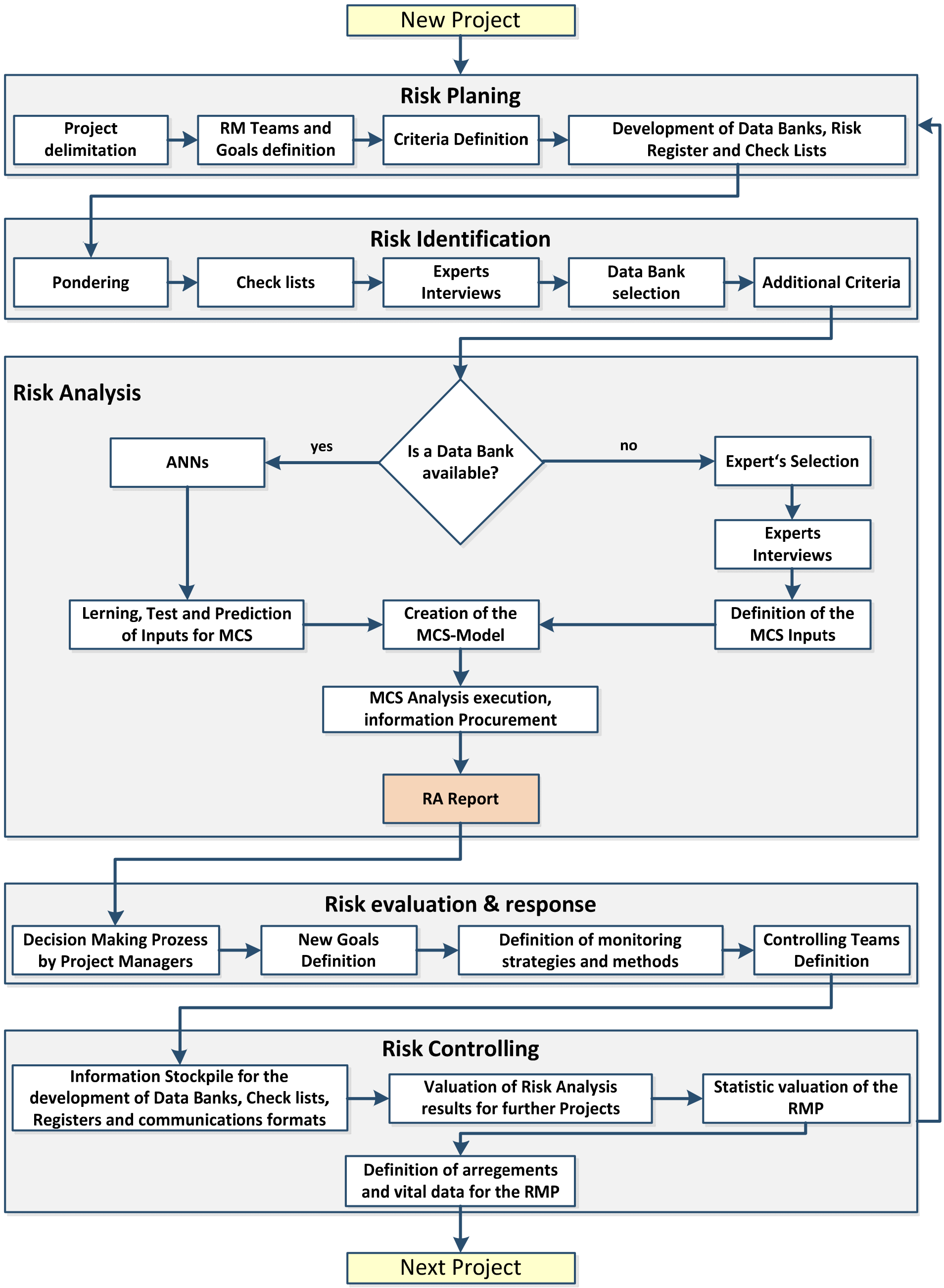



Figure 13: Proposed Risk Management Procedure

Databases, checklists, statistical evaluations and definition of important values and settings for defining scenarios are here performed. Risk controlling permits to gather the gained information an experiences obtained in the development of the RMP for the current project and compile it to the general RMP; in this form the Databases, checklists and registers are continuously updated and their format reviewed. Risk assessments like for example percentile analysis for scenarios can be reviewed and justified and at some point to compare the output for different confidence levels.

As a consequence it is vital for the construction industry to understand RM and to perform quantitative risk analysis with at least MCS as stochastic method. In the real world of construction projects, there are two main goals. The first one is to provide certainty to the project stakeholders and in second term, to achieve a project with the planned goals in time, cost and quality. While implementing a formal risk management process and system for a single project or as part of a company's policies, the project management team is approaching a proactive behavior that will provide tangible and substantial benefits that will contribute to the project success.

## 29.5 Conclusion

The utilization of the ANNs together with the MCS allows increasing the certainty in the data by determining the inputs for the simulation process. The learning process contained in the ANNs permits to reduce the range variation (maximal and minimal values used with the distribution functions and consequently in the histograms) delivered by the MCS. This process mimics the human procedure, every deliberation carried out by experts, resumes the evaluation of similar criteria and experiences from completed similar situations, and therefore the learning process of the ANNs reproduces this evaluation system with high liability. Pondering by the other side does not permit to perform such reliable quantitive valuation; the subsequent utilization of MCS permits to aggregate variations in a smaller range together as correlations with other criteria. Finally the MCS delivers better risk analysis and a reliable quantification of risks.

Another advantage is that the learning process permits to include considerations of uncertainty. In the presented example every result was created for the testing of the ANNs. When real data are collected, they represent real results, thus the ANNs will learn to simulate the considerations of uncertainties and would provide results that could be nearest to the reality.

An important hurdle for the ANNs is the required Data Bank. One of the most characteristic properties of the construction industry is the uniqueness of every infrastructure project; therefore the variations in the criteria are not constant or similar in many cases. This can complicate the development of a liable Data Bank; contrary to it, the consideration of text and uncertainty influences in the collected criteria may even confer more certainty and flexibility once a Data Bank is created. The combinations of these two risk analysis techniques possess a great potential for implementing risk management with the use of defined databases. The project managers usually rely in expert support for determining cost estimates, project planning, resources needed, etc. ANNs are an ideal candidate to provide this expertise once an acceptable database is available. For example, if a set of cost estimate data is available, then an ANN can be built base on that data and total cost predictions can be obtained while simulating the networks.

This information will be very useful for setting up the input ranges used in MCS while working with the input distribution functions. It can be argued that this will require extra work; however, this work can be done as a whole effort by a consultant and get the company's staff trained at the same time. In really, performing risk analysis does not require a considerable extra amount of time or effort to a project manager, especially if assistance is provided by a risk manager. A considerable advantage for the use of this new methodology is that it has the support of two reliable risk analysis techniques and both have a reliable record in the industry, especially MCS.

Storing the knowledge is a plus of the proposed methodology. In other words, having built a database with the support of different experts and from several sorts of projects, invaluable information is a solid reference for future project decisions. The research project of the Institute for Construction Management Munich has shown that collecting real data of infrastructure projects and their analysis will enable the companies to predict risks – hazards and chances – of future projects using artificial intelligence methods (ANNs) combined with simulation methods (MCS).

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